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14. ABSTRACT

The Optical 3-Way Handshake (O3WHS) protocol was developed under the Defense Advanced Research Projects Agency CORONET project. It meets the stringent resource allocation requirement of a dynamic terabit optical network. A simulation of O3WHS operations in a simple network using OMNeT++ network simulation tool has been presented here and the results have been analyzed. This simulation has potential for application to larger heterogeneous networks with software-defined optical networking architecture.

15. SUBJECT TERMS

dynamic optical networking, CORONET, O3WHS, SDON, OMNeT++

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1. Introduction

The Defense Advanced Research Projects Agency (DARPA) concluded a project called CORONET in 2015 that took a closer look at the requirements for the next-generation terabit speed optical networks. It aimed at finding new architectures and protocols to fulfill the following requirements[1]:

- A connection setup blocking probability requirement of less than 10^{-3}
- A connection setup time of less than 50 ms round-trip fiber transmission delay

The blocking probability is defined as the probability that a packet will be blocked because all channels are being used by other packets.

Among many innovations, the CORONET project came up with a new and innovative protocol called 3-way handshake for optical resource or optical 3-way handshake (O3WHS) and configuration management. We will use O3WHS to distinguish it from similar protocol at the Transmission Control Protocol (TCP)/IP layer of the Internet.

The original DARPA CORONET program emulated the O3WHS protocol on a network topology covering a fictitious global network[1] modeled on existing commercial nodes. It consisted of 100 nodes (80 small and 20 large) of which 75 were inside the continental United States (CONUS). The total number of links was 136. The network nodes had maximum nodal degree of 5 and average nodal degree of 2.7. An Optimized Network Engineering Tools platform was used to model this complex topology.

A need exists for implementing and modeling O3WHS on heterogeneous and multidomain networks to experiment with different use cases. In the current work we simulate O3WHS in a popular program called OMNeT++[2] for that purpose. It is an open-source discrete event simulator tool written in C++ language. It has been chiefly applied to the modeling of communication networks but can be adapted to other distributed and parallel systems. In particular, we use its INET framework for O3WHS simulation. It provides models for TCP, IPv4, IPv6, Ethernet, IEEE802.11b/g, Multi-Protocol Label Switching, Open Shortest Path First (OSPF v4), and several other protocols. It also includes the Quagga routing daemon. Our aim in the current work is to initially simulate a simpler network topology that will provide a proof of concept for its applicability to O3WHS protocol.

2. O3WHS Protocol

The O3WHS protocol consists of 3 stages in which the path information is collected and finalized. Figure 1 presents a step-by-step description of the O3WHS protocol.

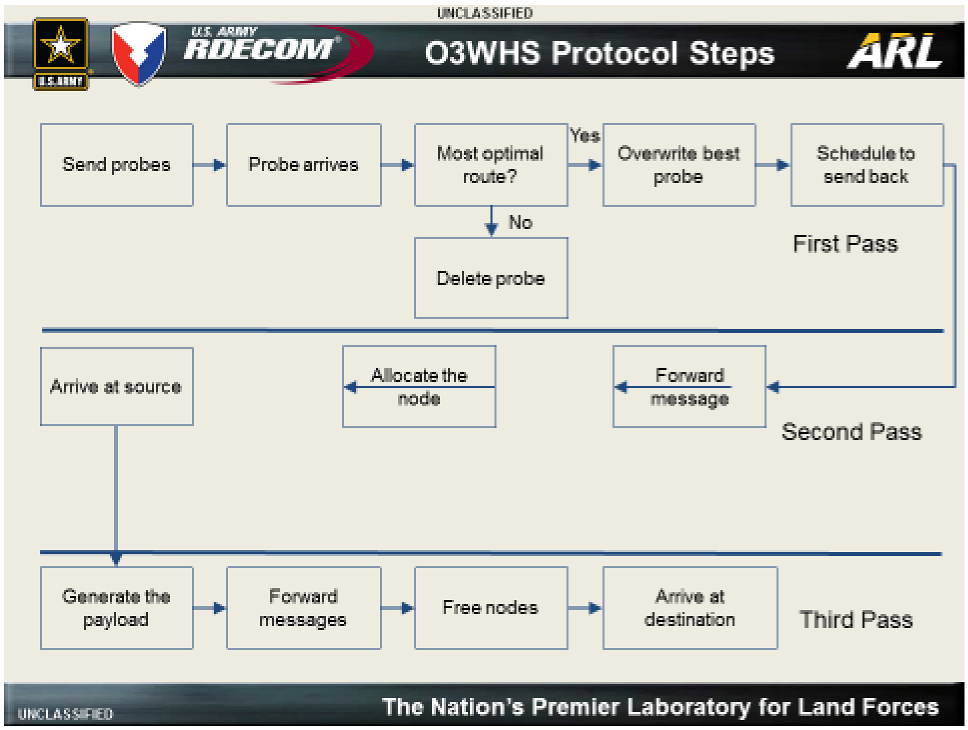

Fig. 1 O3WHS protocol steps

The steps in the 3 stages are given as follows:

1) First Pass

The source node sends probes to the destination node on all possible paths. As the probe goes through different nodes, it collects the routing information.

2) Second Pass

a. The destination node receives the node and link information for all probed paths and calculates the best path optimized according to some performance metric (e.g., minimization of delay, minimization of needed wavelength conversion).

b. It then sends an acknowledgment signal back to the source node on that best path and allocates the node resources (e.g., bandwidth on that path at the same time). This step makes sure that path resources are not used by another request.

3) Third Pass

The source node sends the data payload to the destination node on the chosen best path.

3. The Network Model

We consider a network topology of 8 nodes forming a ring and the ninth central node connecting to 2 ring nodes (Fig. 2).

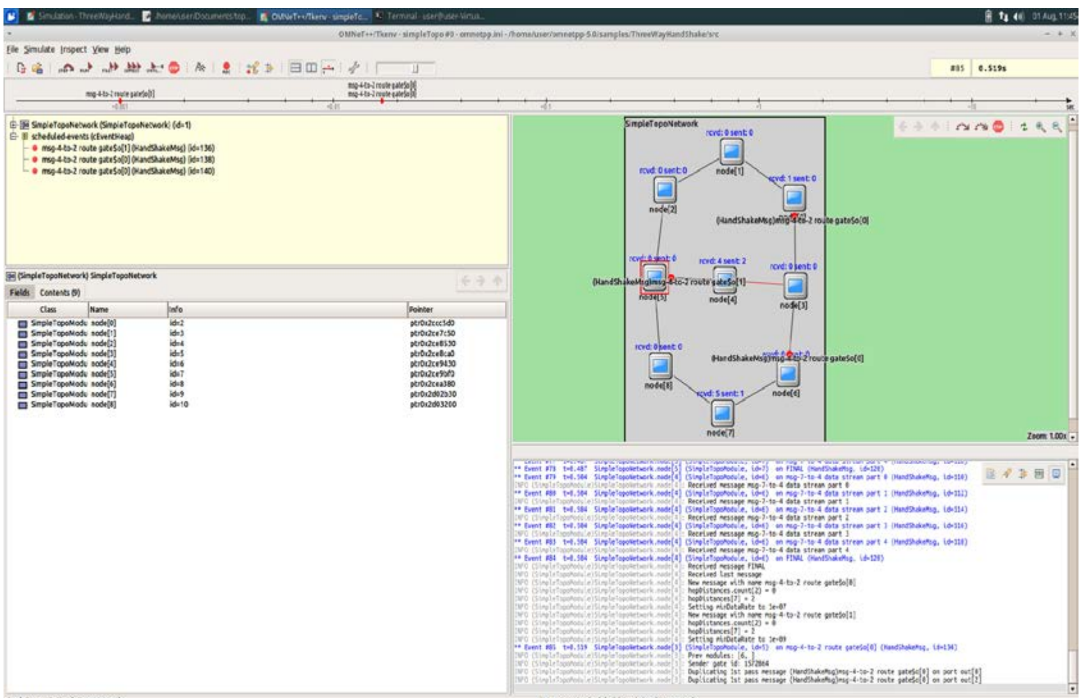

Fig. 2 A simple network topology and snapshot of the runtime with code

After working with this preliminary network to gain experience, another network with mesh topology was used that encompassed CONUS (Fig. 3).

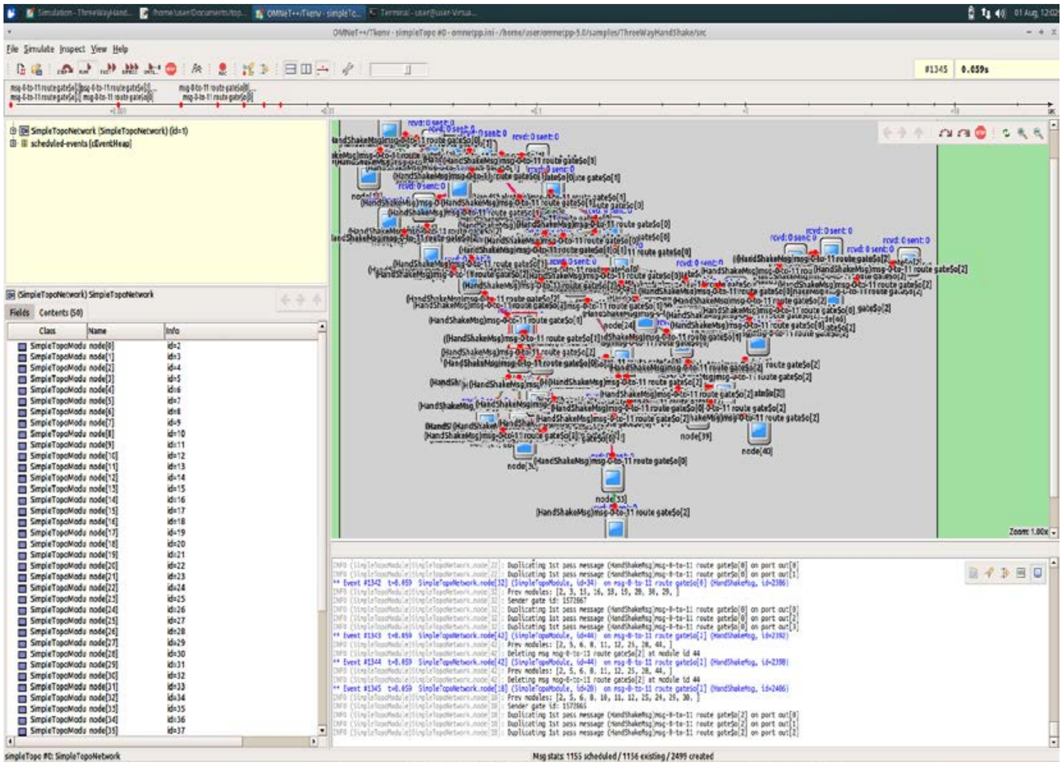

Fig. 3 CONUS network with mesh topology

Because the program cannot handle too many probes used in the first pass, constraints were put on some network parameters, such as expiration time and maximum hop count, to limit their number. The following values were used for the O3WHS protocol element attributes for this purpose:

- expirationTime = 0.08 s. This is the time period after which the packet ceases to exist.
- dataStreamSize = 5 packets. This is the number of packets in the data payload.
- pass2WaitTime = 0.05 s. This is the time period applicable to pass 2. The source node waits for this period before the next step.
- pass2DatarateFactor = 2. This is the scale of how much better bandwidth must be required for one path to be favored over another.

4. Results and Discussion

The experiment proved the O3WHS protocol does not apply perfectly to traditional networks. The exponential growth of probes makes an all-routes check inefficient at moderate scales. In addition, limiting the probes to only a few paths is not as

simple with traditional networks as with optical networks, where wavelength division multiplexing allows the probes to follow the same physical route while traveling different wavelengths.

A question arises whether the new approach to configuration management and resource allocation in O3WHS can be used for nonoptical networking to improve performance. The O3WHS is written and designed for Optical Transport Network hierarchy as a natural and efficient replacement for TCP. It uses multipath probing to ensure that a path is always available for transport. Traditional TCP networks do not benefit from probing paths because their routes are already set using routing tables. They also do not benefit from optimizing wavelength conversions, a core feature of O3WHS. The idea of using least-loaded routing on optical networks may be new, but traditional networks already apply their own optimization algorithms to ensure their routes are as efficient as possible. A better solution for optimizing networks that use multiple paths without optical networking is something like multipath TCP (MPTCP), which increases network throughput for machines that are both on MPTCP connections and have multiple paths.

6. Conclusions

This investigation has proved that OMNeT++ can be used to simulate the O3WHS protocol in a simplified network topology. The behavior of the performance metrics met the expectations.

This approach can be used for existing and planned Department of Defense optical networks based on new paradigms like software-defined optical networking (SDON).[3] In the future, we want to investigate the following issues related to O3WHS:

- How to find multiple shortest paths for routing?
- What is the optimum number of nodes and links in a given topology (e.g., star, mesh) for realizing the benefit of O3WHS?
- What is the best way to integrate the SDON approach with O3WHS?
- What advantage, if any, does O3WHS have over Generalized Multiprotocol Label Switching optical protocol?
- Is it possible to modify O3WHS to improve its performance?

7. References

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List of Symbols, Abbreviations, and Acronyms

CONUS	continental United States
DARPA	Defense Advanced Research Projects Agency
IP	Internet Protocol
MPTCP	multipath TCP
O3WHS	optical 3-way handshake
OSPF	Open Shortest Path First
SDON	software-defined optical networking
TCP	Transmission Control Protocol

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